INDOOR AIR QUALITY ASSESSMENT

Winchester Fire Department
32 Mount Vernon Street
Winchester, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of the Winchester Health Department, an indoor air quality assessment was done at the Winchester Fire Department (WFD) on 32 Mount Vernon Street in Winchester, Massachusetts. The assessment was conducted by the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA). The request was prompted by occupant complaints of dizziness and nausea that they attributed to indoor environmental conditions.

On July 18, 2003, a visit was made to the WFD by Cory Holmes and Shawn Sullivan, Environmental Analysts in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) program to conduct an indoor air quality assessment.

The fire station is a slate roofed two-story red brick building constructed in the early 1900's. The station was renovated in 1984, during which (1) an addition was added to the existing building, (2) the heating, ventilation and air conditioning (HVAC) system was upgraded and (3) new windows were installed. The building maintains its original slate roof.

Plans to repair/replace the slate roof are currently being examined. The building has experienced chronic water damage over the years and is the subject of discussion later in the Moisture/Microbial Concerns section of this report. It was reported by WFD officials that the Town of Winchester was considering commissioning a building envelope study to determine if the structural integrity of the building could support a new roof.

The ground floor of the WFD contains the engine bay and the watch desk. The second floor contains bedrooms (for overnight staff), a locker room, a weight room, office space and a kitchen/lounge. Windows are openable throughout the building. The front of the building has three garage doors allowing vehicles to exit the engine bay (see cover photo). A stairwell connects the engine bay to the second floor. Two fire poles with access to the engine bay are located on the second floor hallway near berthing areas.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Air tests for ultrafine particulates (UFPs) were taken with the TSI, P-Trak ™ Ultrafine Particle Counter Model 8525.

Results

The station is staffed 24 hours a day, seven days a week and has an employee population of approximately 10. The station is visited by approximately 5-10 members of the public on a daily basis. The tests were taken under normal operating conditions. Test results for general air quality parameters (e.g. carbon dioxide, temperature and relative humidity) appear in Table 1. Test results for ultrafine particulates and carbon monoxide are listed in Tables 2 & 3.

Discussion

Ventilation

It can be seen from the tables that the carbon dioxide levels were below 800 parts per million (ppm) in all areas surveyed, which indicates adequate air exchange by the ventilation system. Ventilation is provided to interior rooms by several air handling units (AHUs) located in the attic. AHUs introduce fresh air into the system through intake vents on the roof (see Picture 1). The amount of outside air introduced is controlled by an actuator connected to intake louvers (see Picture 2). Conditioned air is delivered via ducted wall or ceiling mounted air diffusers. Return vents in the main hallway and common areas (see Picture 3), draw air back to AHUs via ductwork. These systems were in operation during the assessment. WFD officials who were present and asked were not aware if a preventative maintenance program was in place for air handling equipment.

Ventilation for perimeter rooms (e.g. berthing areas and offices) is provided by unit ventilators (univents) (see Picture 4). Univents draw air from outdoors through fresh air intakes on exterior walls of the building (see Picture 5) and return air through air intakes at the base of each unit (see Figure 1). Fresh and return air are mixed, filtered, heated and provided through fresh air diffusers in the top of the units. A number of univents were deactivated during the assessment. Therefore no means of mechanical fresh air was being provided to these areas.

A vehicle exhaust ventilation system is installed in the engine bays to remove carbon monoxide and other products of combustion; the system is described in detail under the Vehicle Exhaust portion of this report.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings were measured in a range of 73^{o} F to 77^{o} F, which were within the BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 43 to 68 percent, some of which were above the BEHA recommended comfort guidelines. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. During winter months outdoor relative humidity levels tend to drop. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northern part of the United States.

Microbial/Moisture Concerns

The building has experienced problems with water penetration, most notably on the second floor. Throughout the building water leaks were evidenced by water damaged plaster on walls, stained ceiling tiles, peeling paint and efflorescence (see Pictures 6-8). Water-damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired. Efflorescence is a characteristic sign of water damage to building materials such as brick or plaster, but it is not mold growth. As moisture penetrates and works its way through mortar around brick, water-soluble compounds dissolve, creating a solution. As the solution moves to the surface of the brick or mortar, water evaporates, leaving behind white, powdery mineral deposits. This condition indicates that water from the exterior has penetrated into the building.

A number of conditions were observed which potentially provide means of water penetration into the building:

- Breaches/holes were observed in the gutter/downspout system (see Pictures 9 & 10). Lack of proper roof drainage can allow rainwater to run down the side of the building and pool on the ground at the base of the building against exterior walls. The freezing and thawing action of water during winter months can create cracks and fissures in the foundation.
- Small trees/shrubs and other plants were seen growing in close proximity to the exterior of the building (see Picture 11). The growth of roots against the exterior walls as well as spaces between the tarmac and exterior walls of the building can bring moisture in contact with wall brick and also lead to cracks and/or fissures in the foundation below ground level.
- Missing/damaged mortar around brick and an open utility hole were observed on the exterior of the building (see Pictures 12 & 13).

Each of these conditions compromises the integrity of the building envelope and can provide a means for water penetration into the building. Repeated water damage to porous building materials can result in microbial growth. The US Environmental Protection Agency and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24-48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth.

Vehicle Exhaust

Under normal conditions, a firehouse can have several sources of environmental pollutants present from the operation of fire vehicles. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds;
- Water vapor from drying hose equipment;
- Rubber odors from new vehicle tires; and
- Residues from fires on vehicles, hoses and fire-turnout gear.

Of particular importance is vehicle exhaust. The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon monoxide, carbon dioxide, water vapor and smoke. Of these materials, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). No measurements of carbon monoxide taken during the assessment exceeded the NAAQS.

Using carbon monoxide solely to detect sources of combustion pollutants has a major drawback. If the source of combustion pollutants is allowed to dilute in a large volume of air within a building, carbon monoxide concentrations may decrease below the detection limits of equipment. The process of combustion produces airborne liquids, solids and gases (NFPA, 1997). The measurement of airborne particulates, in combination with carbon monoxide measurements can be used to pinpoint the source of combustion products.

The combustion of fossil fuels can produce particulate matter that is of a small diameter (10 μm), which can penetrate into the lungs and subsequently cause irritation. BEHA air monitoring for airborne particulate was conducted with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitor is useful as a screening device, in that it can be used as a tracker to identify the source of airborne pollutants by counting the actual number of airborne particles. The source of a producer of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cm^3 of air increases as the UPC is moved closer to the source of particle production. While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or that particles are penetrating through spaces in doors or walls, it cannot be used to quantify whether the NAAQS PM_{10} standard was exceeded.

The primary purpose of these tests at the fire station was to *identify and reduce/prevent* pollutant pathways. Air monitoring for ultrafine particles was conducted around each door with access to the engine bay as well as within each room in the station (e.g. offices, berthing areas). Several sets of readings were taken prior to and during diesel engine operation. As would be expected, the highest readings for ultrafine particulates were taken in the engine bay during diesel engine operation.

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bay during vehicle idling. The system consists of a large exhaust vent located at floor level on the West side of the engine bay (see Picture 14). Fire

Department personnel reported that several make up air vents were retrofitted on the East side of the engine bay (see Picture 15), to pressurize the engine bay toward the exhaust vent. This system is reportedly in operation 24 hours a day.

Although the engine bay is equipped with a mechanical ventilation system, a number of pathways for vehicle exhaust and other pollutants to move from the engine bay into occupied areas were identified (see Figures 2 & 3). The stairwell doors (off the engine bay) leading to the upstairs had spaces beneath doors from which light could be seen penetrating (see Picture 16). Clamshells (i.e. closures) around fire poles did not close completely creating spaces (see Picture 17). Elevated levels of UFPs were measured near these areas after operation of fire fighting vehicles (see Tables 2 & 3). These results demonstrate that the breaches are serving as pathways for diesel exhaust and particulates to move from the engine bay into occupied areas of the station.

Univents in second floor offices were in use and windows were open during operation of fire fighting vehicles. Under certain wind and weather conditions exhaust emissions can penetrate or be drawn into the room (called entrainment) through univent air intakes or open windows. Another possible pathway for exhaust emissions is through utility holes. The ceiling/walls of the engine bays are penetrated by holes for utilities. These holes can present potential pathways into occupied areas if they are not airtight. Each of these conditions presents a pathway for air to move from the engine bays to occupied areas of the station. In order to explain how engine bay pollutants may be impacting the second floor and adjacent areas, the following concepts concerning heated air and creation of air movement must be understood.

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.

- As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g. vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- The operation of HVAC systems (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bay can pressurize the engine bay. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the second floor, sealing of these pollutant pathways should be considered.

Other Concerns

As discussed, WFD staff could not identify the last date of preventative maintenance done on air handling equipment. The access panel for the AHU filters in the attic could not be located; therefore the condition of filters could not be examined. Filters in univents were examined and are made of a metal mesh material (see Picture 18). This type of filter provides minimal respirable dust filtration and must be physically cleaned by hand. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase in filtration, each piece of air handling equipment should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Continue to operate the engine bay vent system on a continuous basis to create negative pressure in the engine bay. Consider installing an automatic control to activate the engine bay exhaust system as engine bay doors open.
2. Keep all doors and windows accessing engine bays closed at all times.
3. Ensure doors around engine bay fit completely flush with threshold. Seal doors on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
4. Examine methods to seal spaces and holes around fire poles. Considering contacting the manufacturer for advice.
5. Under certain wind and weather conditions second floor windows should be shut and univents may be temporarily deactivated during engine operation to prevent entrainment of vehicle exhaust.
6. Ensure all utility holes are properly sealed in both the engine bay and their terminus to eliminate pollutant paths of migration.

7. Work with Winchester town officials to develop a preventative maintenance program for all HVAC equipment department wide.
8. Change filters for HVAC equipment as per the manufacturer's instructions or more frequently if needed. Examine HVAC equipment periodically for maintenance and function. Examine the feasibility of upgrading filters.
9. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of building occupancy independent of thermostat control (excluding engine bay exhaust system).
10. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994). Consult a ventilation engineer concerning re-balancing of the ventilation systems.
11. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
12. Continue with plans to conduct building envelope study, to determine current conditions and future improvements to address water penetration issues.
13. Replace/repair water-damaged ceiling tiles and wall plaster. Examine the area above and behind these areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial.

14. Replace or repair damaged gutters and downspouts.

15. Remove plants from the wall/tarmac junction around the perimeter of the building.

16. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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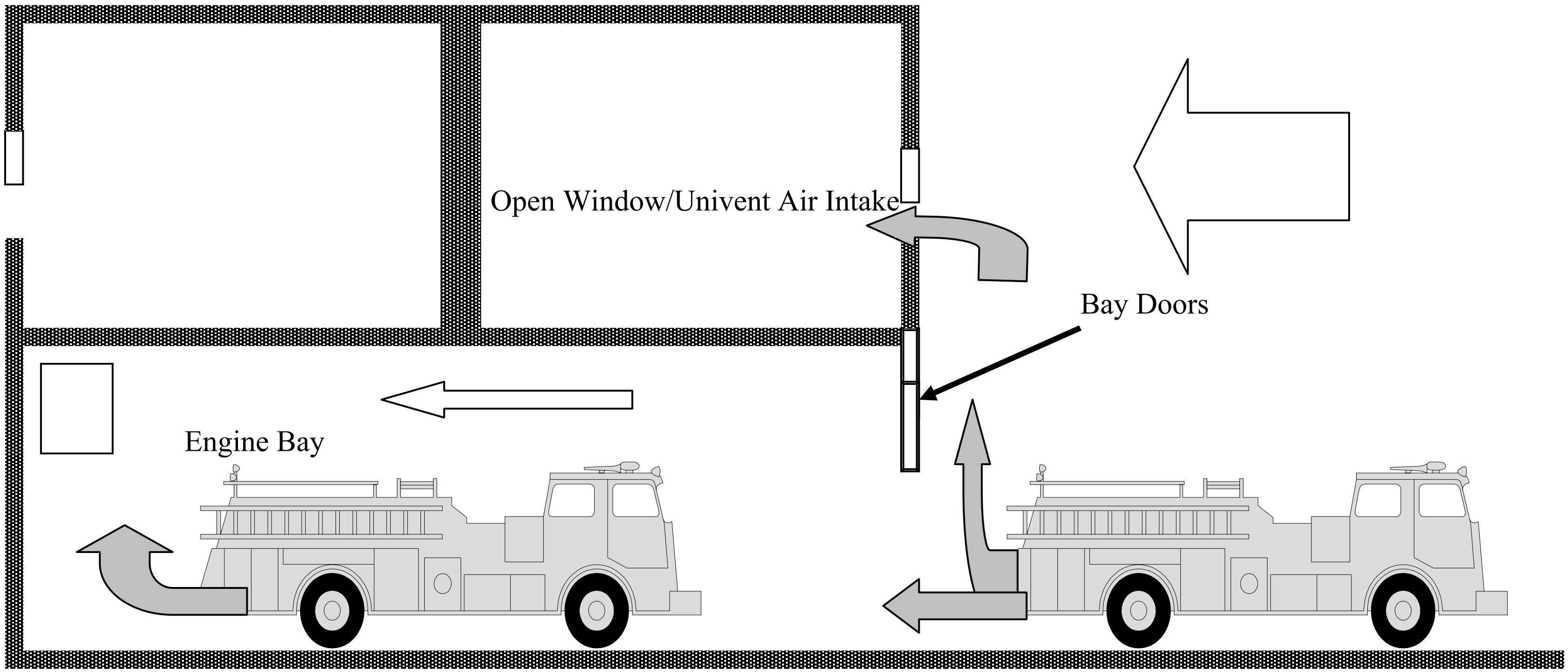
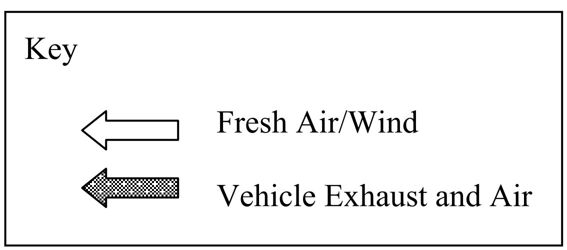
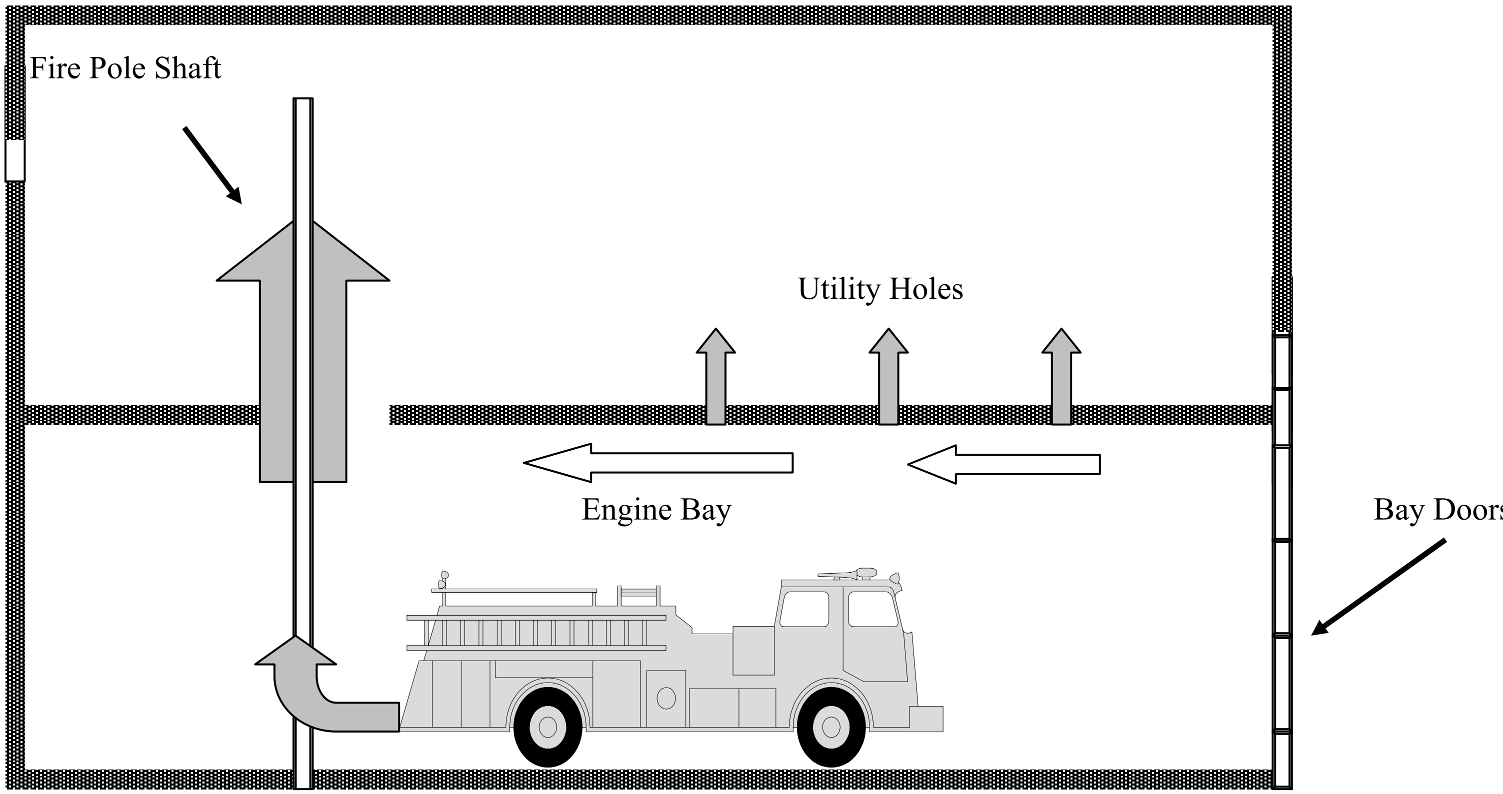
Figure 2 **Engine Bay & Potential Entrainment of Vehicle Exhaust Through Second Floor Open Windows/Univent Air Intakes**

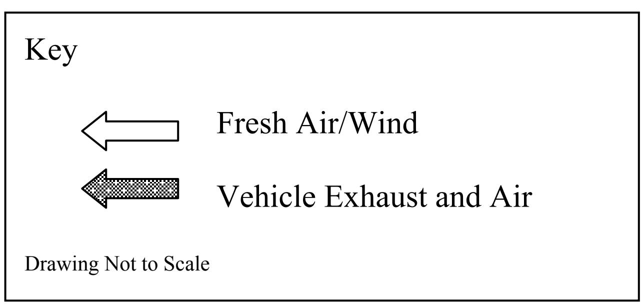




Drawing Not to Scale

Figure 3 **Potential Pathways of Air and Pollutant Movement from Engine Bay into Adjacent Areas**





Picture 1

Outside Air Intake for Attic Air Handling Equipment

Picture 2

Actuator in Attic Controlling Outside Airflow into Attic AHUs

Picture 3

Ceiling-Mounted Return Vent

Picture 4

Univent in Berthing Area

Picture 5

Fresh Air Intake Grills for Fan Coil Units

Picture 6

Water Damage Ceiling Plaster

Picture 7

Water Damaged Wall Plaster and Efflorescence

Picture 8

Water Damaged Ceiling Tiles

Picture 9

Hole in Gutter System

Picture 10

Breach in Downspout

Picture 11

Shrubbery/Plants Growing Against Building

Picture 12

Missing/Damaged Mortar

Picture 13

Open Utility Holes in Brick

Picture 14

Exhaust Vent on West Side of Engine Bay

Picture 15

Retro-fitted Supply Vents on East Side of Engine Bay

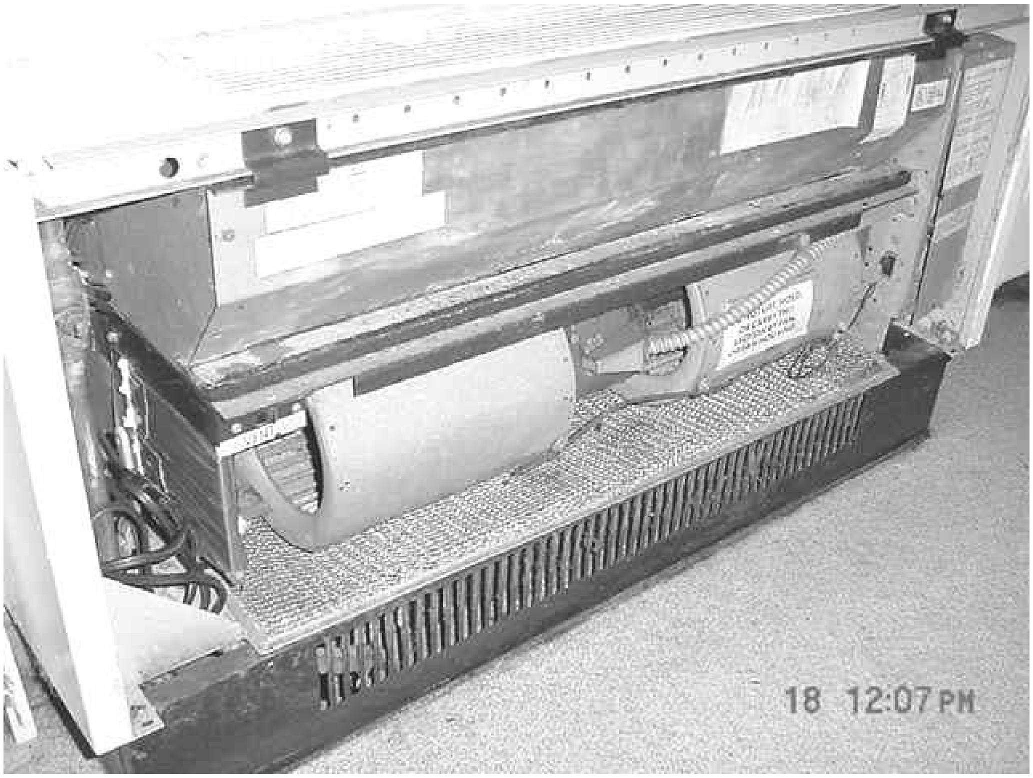
Picture 16

Light Penetrating Through Space Under Stairwell Door to Engine Bay

Picture 17

Hole/Spaces around Fire Pole

Picture 18



Metal Mesh Filter in Univent

TABLE 1

Indoor Air Test Results –Winchester Fire Department, Winchester, MA July 18, 2003

Location	Carbon Dioxide (*ppm)	Temp °(F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	460	76	62					Moderate traffic Cloudy, humid
Conference Room	550	77	57	0	N	N	N	
Stairwell Eng Bay	445	76	68					
Lieutenant	674	77	57	0	Y	Y	N	
Fire Pole								
Locker Room	631	76	56	0	N	N	Y	CT
Berthing 2	498	76	59	0	Y	N	N	
Berthing 7	496	76	58	0	Y	Y	N	
Chief	580	73	50	2	Y	Y	N	AC on
Berthing 5	500	76	58	0	Y	Y	N	Window open

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results –Winchester Fire Department, Winchester, MA **July 18, 2003**

Location	Carbon Dioxide (*ppm)	Temp °(F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Kitchen	760	75	43	3	Y	Y	Y	AC on Window open
Watch Desk	530	76	64	2	Y	N	N	AC on

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%